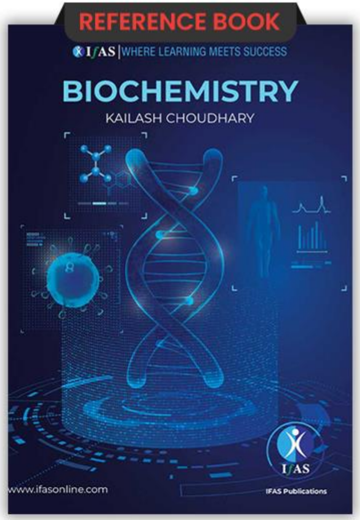
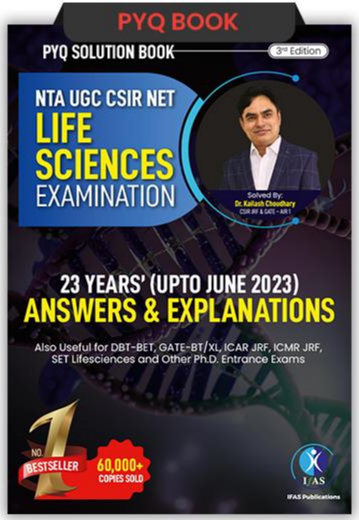
मंज़िल उन्हीं को मिलती है जिनके सपनों में जान होती है, पंख से कुछ नहीं होता हौसलों से उड़ान होती है।

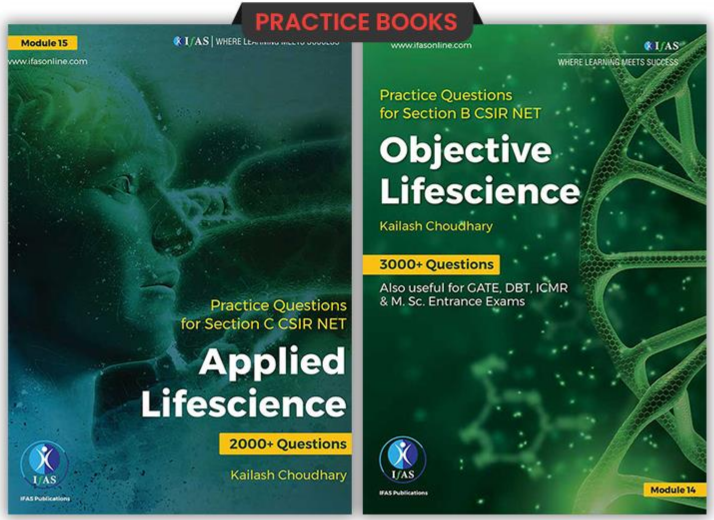
CSIR NET – Life Science

Unit 1: Biochemistry

03 Solution and Colligative Properties





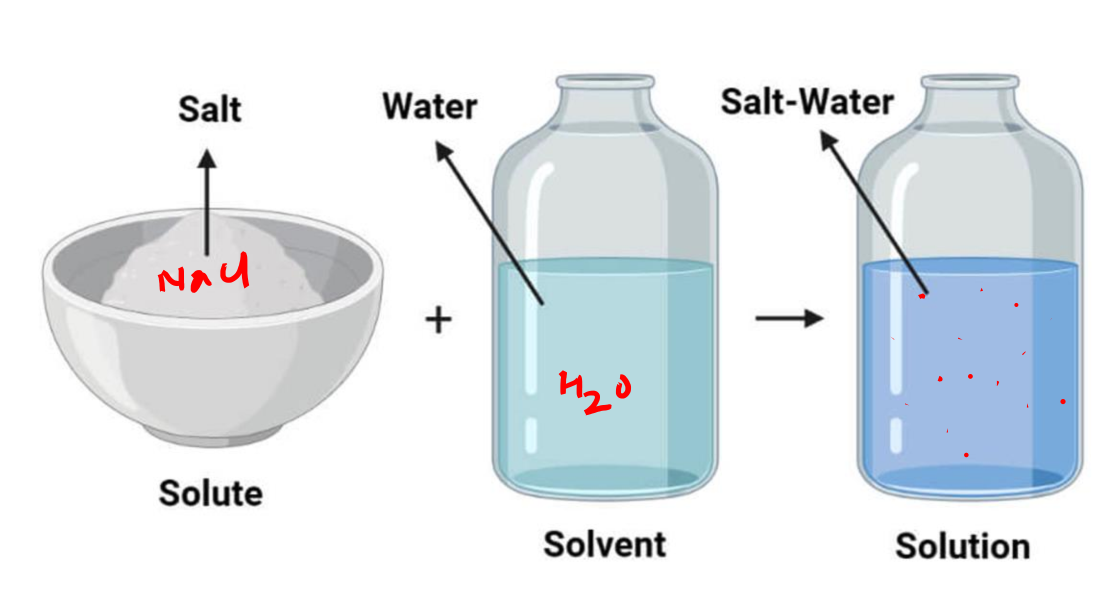


Points to be covered in this Lecture

- Percentage and ppm Solution
- Molar Solution
- Normal Solution
- Dilutions of Solution
- Ionic Strength of Solution
- Colligative properties of Solution ✓

What is a Solution?

A solution is **a homogeneous mixture of one or more solutes dissolved in a solvent.**



Weight and Volume Units

$D = \frac{M}{V}$ Mass = D × V

Weight	Volume
Kilogram	Liter
Gram	Milli Liter
Milli Gram	Micro Liter
Micro Gram	Nano Liter

1 Kg water = 1 litre water D = 1

10^{-3} milli (m)
10^{-6} micro (μ)
10^{-9} Nano (n)
10^{-12} Pico (p)

10^{3} Kilo K
10^{6} mega (million) M
10^{9} Giga (billion) G
10^{12} Terra (Trillion) T

Different Types of Solutions

Weight by Weight (W/W)

- Add 5g Glucose in 95 g of water

w/w

Weight by Volume (W/V)

- Mix 5g Glucose in 100 mL of Solution

w/v

Volume by Volume (V/V)

- Add 5 mL Ethanol in 95 mL of water

v/v

Limitation
concn may change with tempr or pressure change

Solution Used in Laboratory

1. % Solution
2. PPM Solution
3. Molar Solution
4. Normal Solution

w/w
w/v
v/v

Percentage solution

'x' grams of solute per 100 mL of solution = x %

Used for making concentrated solutions

1 g in 100 mL = 1 %

10g in 100 mL = 10 %

0.01g in 100 ml = 0.01 %

Practice Question

Prepare 100 mL of 10 % Glucose

• 10g glucose in 100 mL.

Prepare 10 mL of 25 % sucrose

100 mL $\longrightarrow$ 25 g

1 mL $\longrightarrow$ $\frac{25}{100}$ g

10 mL $\longrightarrow$ $\frac{25}{100} \times 10$ g

= 2.5 g

PPM solution : Parts of solute (mg) in 1 million part of solvent (μL).

'x' milligrams of solute per 1000 mL of solution = x ppm
'x' milligram of solution in one million microlitre = x ppm

- Used for making dilute solutions
- PPM is 10,000 times dilute than % solution

5 ppm Glucose : 5 mg ⟶ 1000 mL
50 ppm Glucose : 50 mg ⟶ 1000 mL
250 ppm Glucose : 250 mg ⟶ 1000 mL

Practice Question

Prepare 10 ppm Glucose (50mL)

10 mg in 1000 mL

1000 ml $\longrightarrow$ 10 mg

1 mL $\longrightarrow$ $\frac{10}{1000}$ mg

50mL $\longrightarrow$ $\frac{1\cancel{0}}{10\cancel{0}\cancel{0}} \times 5\cancel{0}$ mg

$\frac{5}{10}$ mg = 0.5 mg + water = 50mL

Practice Question

Prepare 250 ml of 50 ppm Glucose

$1000\ mL \longrightarrow 50\ mg$

$1\ mL \longrightarrow \frac{50}{1000}\ mg$

$250\ mL \longrightarrow \frac{5\cancel{0}}{10\cancel{0}\cancel{0}} \times 25\cancel{0}\ mg$

$= \frac{125}{10}\ mg$

$= 12.5\ mg + \text{water} = 250\ mL$

Practice Question

Convert 500 ppm Glucose into % solution

% solution is 10,000 times more concentrated than ppm solution

$$\% = \frac{ppm}{10,000}$$

$$ppm = \% \times 10,000$$

$$\% = \frac{5\cancel{00}}{10,0\cancel{00}} = \frac{5}{100} = 0.05$$

What is one mole ?

Mole is unit of counting for atoms or molecules or object

One mole = 6.023×10^{23} molecules = Avagrado number

$= 6 \times 10^{23}$ molecules

$= 600000000000:000000000000$ molecule

Apply your mind

If our live class has 600 students of age 21-27 years. How many moles of students are present in our class room? [Consider Avogadro No = 6×10^{23}]

(1) $1/6 \times 10^{-23}$ (2) $1/6 \times 10^{-14}$

(3) 6×10^{14} (4) 1×10^{-21}

6×10^{23} students = 1 mole student

$\boxed{1 \text{ student}} = \frac{1}{6 \times 10^{23}} = \boxed{\frac{1}{6} \times 10^{-23} \text{ student}}$

600 student $= \frac{\cancel{600}}{\cancel{6}} \times 10^{-23}$

$= 100 \times 10^{-23}$ mole $= 10^{2} \times 10^{-23}$

$= 10^{-21}$ mole $= 10^{-21}$

Molar solution:

$\frac{\text{Mole}}{\text{Litre}} = M$

1 mole = 6×10^{23} molecules

- 1 Mole of solute in 1000 mL of solution
- Amount of solute in gram equal to its molecular weight will have 1 mole of substance.

NaOH (40D) → 40 g → 1 mole
Alanine (89 D) → 89 g → 1 mole
Glucose (180 D) → 180 g → 1 mole
Sucrose (342 D) → 342 g → 1 mole
Protein (100 KD) 100,000 Dalton → 100,000 g → 1 mole

Apply your mind

How you will prepare 1000 mL of 10 mM glucose (MW=180) ?

(1) Add 18 g of glucose in 1000 mL

(2) Add 1.8 g of glucose in 1000 mL

(3) Add 10 g of glucose in 1000 mL

(4) Add 1 g of glucose in 1000 mL

$10 \times 10^{-3} \times 180\ g$ (1000 mL)

$\cancel{10} \times \frac{1}{10\cancel{00}} \times 18\cancel{0}\ g$

$\frac{18}{10}\ g = 1.8\ g$

Apply your mind

How to prepare 10 mL of 0.1 Molar glucose (MW=180) ?

1000 mL $\longrightarrow$ 0.1×180 g

1 mL $\longrightarrow$ $\frac{0.1 \times 180}{1000}$ g

10 mL $\longrightarrow$ $\frac{0.1 \times 18\cancel{0}}{10\cancel{0}\cancel{0}} \times 1\cancel{0}$ g

$= \frac{1.8}{10}$ g $= 0.18$ g Glucose

+ water = 10 mL

Apply your mind

Prepare 100 ml of 10 mM Sucrose (MW=342)

2 1 ✓

$1000\ mL \longrightarrow 10 \times 10^{-3} \times 342\ g$

$1\ mL \longrightarrow \dfrac{10 \times 10^{-3} \times 342}{1000}\ g$

$100\ mL \longrightarrow \dfrac{\cancel{10} \times 10^{-3} \times 342}{\cancel{1000}} \times \cancel{100}\ g$

$\longrightarrow 342 \times 10^{-3}\ g = 0.342\ g$

$\longrightarrow 342\ mg$

Apply your mind

What would be the molarity of 1 mg/ml protein (MW=10 KD) solution?

Given

1 mg in 1 mL

1000 mg in 1000 mL

✓ 1 g in 1000 mL

Molecular weight = 10 KD

= 10,000 Dalton

10000 g → 1 molar (1000 mL)

$1 g \rightarrow \frac{1}{10{,}000} M$

$= 10^{-4} M$

$\rightarrow 10^{-4} M = 10^{-1} \times 10^{-3} M$

$= 0.1 \; mM$

$\rightarrow 10^{-4} M = 10^{2} \times 10^{-6} M$

$= 100 \; \mu M$

Apply your mind:

What will be Molarity of Pure water (Mr=18) at 4.0°C (Density =1)?

- 1000 mL ⟶ 1000 g (H_2O)

1000 ml

18 g H_2O ⟶ 1 M

1 g ⟶ $\frac{1}{18}$ M

1000g ⟶ $\frac{1000}{18}$ M = 55.56 M

= 55.6 M.

Normal solution

Used for acid , base or salt (ionic substances)

Amount of solute in gram equal to its equivalent weight in one liter solution

$$\text{Equivalent weight} = \frac{\text{Molecular weight}}{\text{Acidity or basicity}}$$

	Acidity
HCl	1
H_2SO_4	2
H_3PO_4	3
H_2CO_3	2

	Basicity
$NaOH$	1

Apply your mind:

Prepare 100 mL of 0.2 N H_2SO_4 (MW=98 U)

$$\text{Eq wt} = \frac{98}{2} = 49$$

$$1000\text{ mL} \longrightarrow 0.2 \times 49\text{ g}$$

$$1\text{ mL} \longrightarrow \frac{0.2 \times 49}{1000}\text{ g}$$

$$100\text{ mL} \longrightarrow \frac{0.2 \times 49}{10\cancel{00}} \times 1\cancel{00}\text{ g}$$

$$\frac{9.8}{10}\text{ g} = 0.98\text{ g}$$

Dilution of solution

The formula for calculating a dilution is

$$C_1V_1 = C_2V_2$$

μL μL

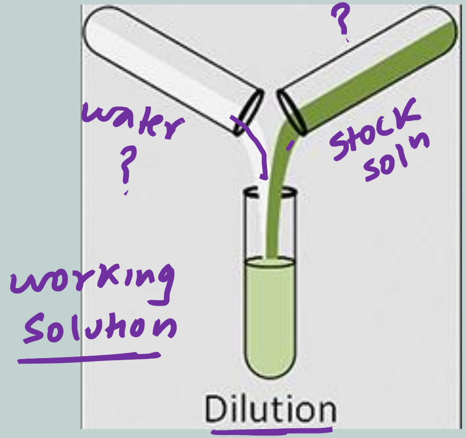
where...

C1 is the concentration of the stock solution.

V1 is the volume to be taken from of the stock solution.

C2 is the concentration of the final working solution.

V2 is the volume of the final working solution.



Apply your mind:

Prepare 100 ml of 5 mM glucose solution from a stock solution having concentration 0.5 M

$V_2 = 100$ mL

$C_2 = 5$ mM

$V_1 = ?$

$C_1 = 0.5$ M

$C_1 V_1 = C_2 V_2$

$\underset{M}{0.5} \times \underset{mL}{V_1} = \underset{M}{5 \times 10^{-3}} \times \underset{mL}{100}$

$V_1 = \dfrac{\cancel{5}^{10} \times 10^{-3} \times 100}{\cancel{0.5}}$

$= 1000 \times 10^{-3}$ mL $= \cancel{1000} \times \dfrac{1}{\cancel{1000}}$ mL $= 1$ mL

- Take 1 mL of 0.5 M glucose and add 99 mL of water to make 100 mL of 5 mM glucose

Apply your mind:

What will be the final concentration of the solute when 10 ml of its 10 M solution is mixed with 990 ml solvent?

C_2 V_1 C_1

(1) 1 M
(2) 0.1 M
(3) 10 M
(4) 0.001 M

$V_2 = 1000$ mL

original mix final

$10 + 990 = 1000$ ml

$C_1 V_1 = C_2 V_2$

$\underset{M}{10} \times \underset{mL}{10} = \underset{M}{C_2} \times \underset{mL}{(990 + 10)}$

$C_2 = \frac{10 \times 10}{1000} = \frac{100}{1000} = 0.1$ M

Apply your mind:

If you mixed 20 mL of 50 mM sodium acetate (NaOAc) with 30 mL of 25 mM glucose, what would be the concentration of each in the final solution?

(1) 50 mM NAOAc, 25 mM Glucose
(2) 20 mM NaOAc, 15 mM Glucose
(3) 30 mm NaOAc, 20 mM Glucose
(4) 40 mM NaOAc, 10 mM Glucose

Final volume (V_2)
$= 20\,mL + 30\,mL = 50\,mL$

$C_1 V_1 = C_2 V_2$

$\underset{mM}{50} \times \underset{mL}{20} = C_2 \times \underset{mL}{50}$

$C_2 = \frac{\cancel{50} \times 20}{\cancel{50}} = 20\,mM$

$C_1 V_1 = C_2 V_2$

$\underset{mM}{25} \times \underset{mL}{30} = \underset{mM}{C_2} \times \underset{mL}{50}$

$C_2 = \frac{\cancel{25} \times 30}{\cancel{50}\,2} = 15\,mM$

Mixing Two Solution

$$C_1 V_1 + C_2 V_2 = C_3 (V_1 + V_2)$$

glucose + glucose ⟶ glucose

0.1 M   0.5 M   ?

100 mL   100 mL   200 ml

$$(0.1 \times 100) + (0.5 \times 100) = C_3 (100 + 100)$$

$$10 + 50 = C_3 \times 200$$

$$C_3 = \frac{6\cancel{0}}{20\cancel{0}} = \frac{3}{10} = 0.3\,M.$$

Apply your mind:

What will be final concentration of solution made by mixing 200 ml of 0.1 M glucose and 400 mL of 0.2 M glucose?

$C_1 = 0.1$ $\quad$ $C_2 = 0.2$ $\quad$ $C_3 = ?$

$V_1 = 200$ $\quad$ $V_2 = 400$ $\quad$ $V_3 = 600$

0.1 ⟵ ⟶ 0.2

$$C_1 V_1 + C_2 V_2 = C_3 V_3$$

$$0.1 \times 200 + 0.2 \times 400 = C_3 \times 600$$

$$20 + 80 = C_3 \times 600$$

$$\frac{1\cancel{00}}{6\cancel{00}} = C_3$$

$$C_3 = \frac{1}{6} M = \underline{0.166 M}.$$

Ionic Strength of Salt

$$I = \frac{1}{2}\sum_{1}^{n} C_i Z_i^2$$

Where,

C_i – ionic concentration

Z_i – ion charges

1 M NaCl ⟶ 1 M Na^+ + 1 M Cl^-

1 M $CaCl_2$ ⟶ 1 M Ca^{+2} + 2 M Cl^-

1 M NaCl ⟶ Na^+ Cl^-

	Na^+	Cl^-
C	1 M	1 M
Z	+1	−1

$$I = \frac{1}{2}\sum C_{Na}\cdot(Z_{Na})^2 + C_{Cl}\cdot(Z_{Cl})^2$$

$$= \frac{1}{2}\sum 1\,(1)^2 + 1\,(-1)^2$$

$$= \frac{1}{2}\sum 1 + 1$$

$$= \frac{1}{2}\times 2 = 1$$

1 M $CaCl_2$ ⟶ Ca^{2+} Cl^{-1}

	Ca^{2+}	Cl^{-1}
C	1 M	2 M
Z	+2	−1

$$I = \frac{1}{2}\sum 1\,(2)^2 + 2\,(-1)^2$$

$$= \frac{1}{2}\sum 4 + 2 = \frac{1}{2}\times 6 = 3$$

Apply your mind

Calculate the ionic strength of a 0.2 M $MgCl_2$

$$0.2\ MgCl_2 \longrightarrow 1\ Mg^{2+} + 2\ Cl^-$$

$$c = 0.2 \times 1 = 0.2 \qquad 0.2 \times 2 = 0.4$$

$$z = +2 \qquad -1$$

$$I = \frac{1}{2} \Sigma\ C_{mg} \cdot (Z_{mg})^2 + C_{cl} \cdot (Z_{cl})^2$$

$$= \frac{1}{2} \Sigma\ 0.2\ (+2)^2 + 0.4\ (-1)^2$$

$$= \frac{1}{2} \Sigma\ 0.2 \times 4 + 0.4 \times 1$$

$$= \frac{1}{2} \Sigma\ 0.8 + 0.4$$

$$I = \frac{1}{2} \times 1.2 = 0.6$$

Apply your mind

PO_4^{-3} HPO_4^{-2}

$H_2PO_4^{-1}$

+1 | −2
+1 |

Calculate the ionic strength of a 0.1 M Na_2HPO_4

2 1

$$1\,Na_2HPO_4 \longrightarrow 2\,Na^+ + 1\,HPO_4^{-2}$$

$c = 0.1$ $\quad 2 \times 0.1 = 0.2 \quad 1 \times 0.1 = 0.1$

$z = +1 \quad z = -2$

$$I = \frac{1}{2} \sum C_{Na} \cdot (Z_{Na})^2 + C_{HPO_4} \cdot (Z_{HPO_4})^2$$

$$= \frac{1}{2} \left(0.2 \times (1)^2 + 0.1 (-2)^2 \right)$$

$$= \frac{1}{2} (0.2 + 0.4)$$

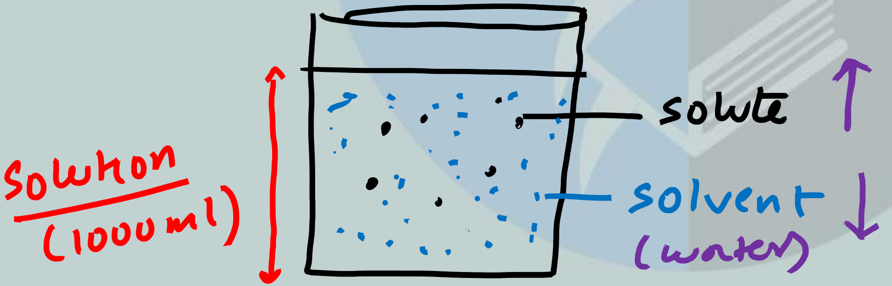
$$= \frac{1}{2} \times 0.6 = 0.3$$

Colligative properties

Properties of solutions that depend

- upon the concentration of solute molecules or ions,
- but not upon the identity of the solute.

Solutes alter the colligative properties of aqueous solutions by lowering the effective concentration of water.



Colligative properties include

- Vapour pressure lowering
- Boiling point elevation
- Freezing point depression and
- Osmotic pressure increase

Solute = ↑

Solution

water = ↓

Effect due to Colligative properties depends on i x C

$M = \frac{mole}{L}$

i = vant hoff factor

Degree of Ionization

0.1 M Glucose < 0.1 M NaCl

$c \times i$ $\quad$ $c \times i$

$0.1 \times 1 < 0.1 \times 2$

$0.1 < 0.2$

Non-Ionic molecules

$i = 1$

Sucrose

Glucose

Glycogen

Proline

Sorbitol

Glycine

Ionic / salts

NaCl $\quad i = 2 \quad$ $1\,Na^{+} + 1\,Cl^{-}$

$CaCl_2$ $\quad i = 3 \quad$ $1\,Ca^{2+} + 2\,Cl^{-}$

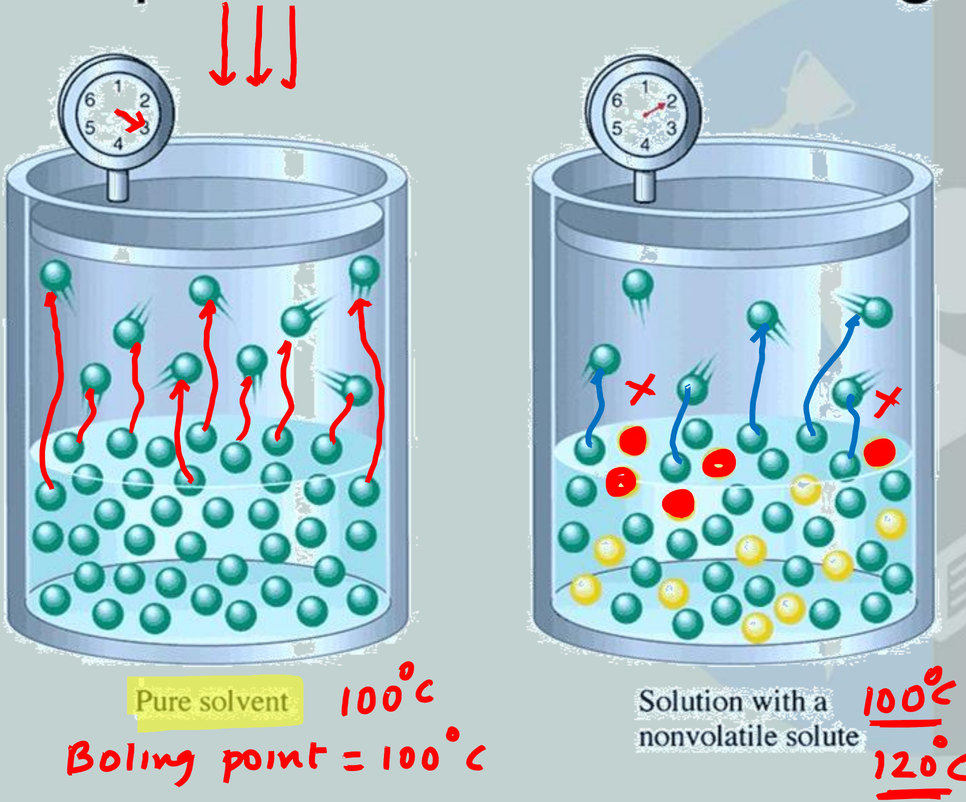
$MgSO_4$ $\quad i = 2 \quad$ $1\,Mg^{+2} + 1\,SO_4^{-2}$

0.1 M Glucose = 0.1 Glycine

$c \times i$ $\quad$ $c \times i$

$0.1 \times 1 = 0.1 \times 1$

Vapor Pressure Lowering

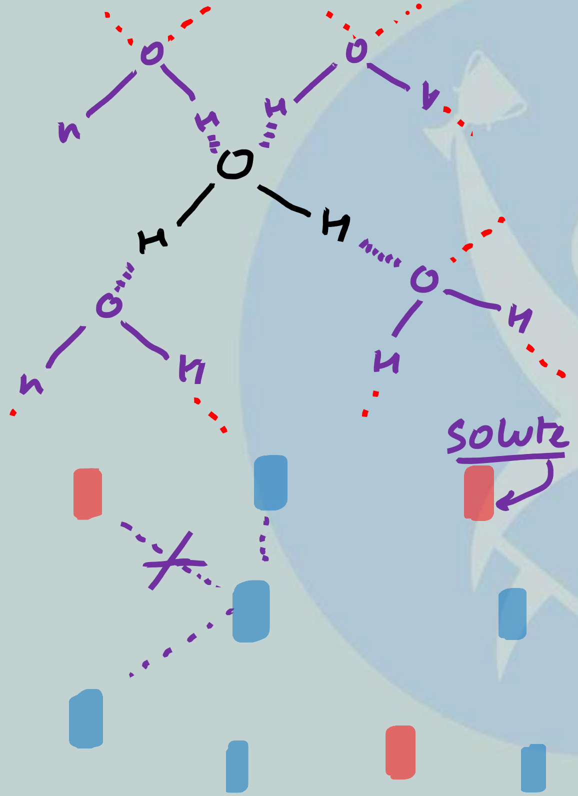


As solute concⁿ increases water concⁿ decreases in solution
Lesser vapours are formed.
Lesser vapour pressure

→ Increase in boiling point

Decrease in freezing point

0°C



Pure water freezes at 0°C

As solute increase conc^n of H_2O decreases at 0°C water will not form all 4 Hydrogen bond → water will not freeze.

Temp^r must be decreased for ice formation.

Increase in Osmotic pressure

Diffusion : High conc^n → Low conc^n
Osmosis : Diffusion of water

The pressure exerted on a solution to prevent osmosis (inflow) with the help of semi-permeable membrane

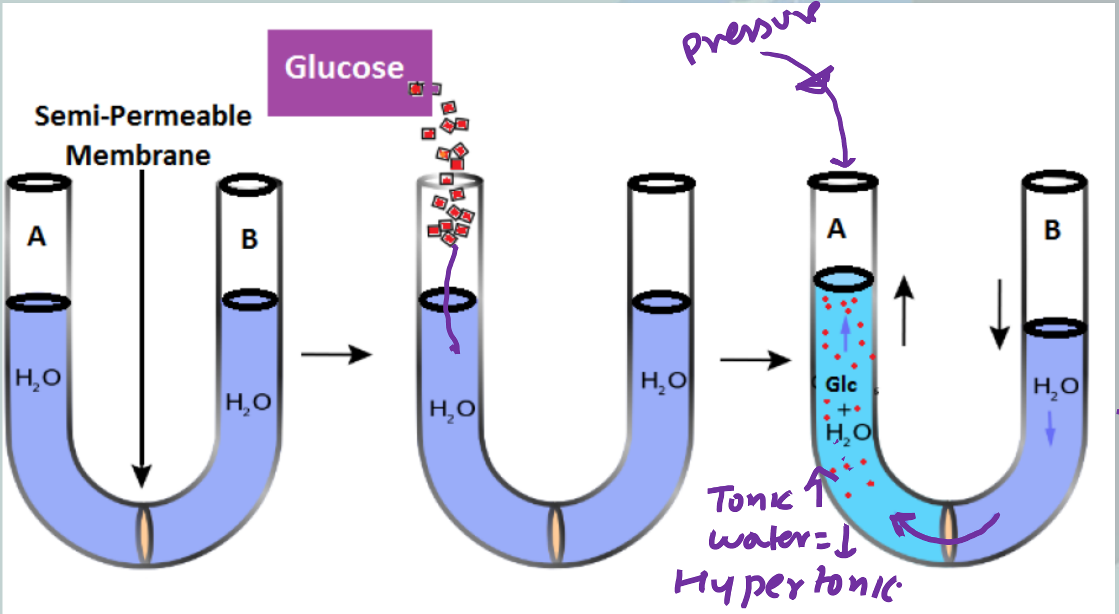


Figure 3: Osmosis through semi-permeable membrane in U-tube

Hypotonic
Tonic = ↓
water = ↑

Osmotic pressure

$\Pi = i\,c\,RT$

i = degree of ionization

c = conc^n (M)

R = gas constant

T = Temp^r in kelvin = $25^\circ C + 273 = 298\,K$

water moves from low osmotic pressure to high osmotic pressure

0.1 M glucose

$= i \times c$

$= 1 \times 0.1$

$= 0.1$

water

0.1 M NaCl

$= i \times c$

$= 2 \times 0.1$

$= 0.2$

Apply your mind

What will be isotonic concentration of solution of sorbitol for 0.2 M KCl ?

(1) 0.2 M sorbitol
(2) 0.1 M sorbitol
(3) 0.4 M sorbitol
(4) 0.6 M sorbitol

$0.2\ M\ KCl = ?\ M\ sorbitol$

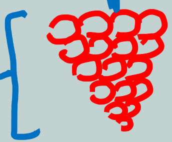
$i \times C = i \times C$

$2 \times 0.2 = 1 \times C$

0.4

1 Grape bunch has 1000 grapes → weight 1 kilogram

1 kg



1 Grape bunch ↔ 1 Grape → 1g

Gram grapes

Isotonic = Number of molecules are same

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